Dec 1st, 12:00 AM

View from the Sky: Mapping corn nitrogen status at the watershed level

Chris Wilkins
Iowa Soybean Association

Suzanne Fey
Iowa State University

Bra Wirt
Iowa Soybean Association

Peter Kyveryga
Iowa Soybean Association

Wilkins, Chris; Fey, Suzanne; Wirt, Bra; and Kyveryga, Peter, "View from the Sky: Mapping corn nitrogen status at the watershed level" (2017). *Proceedings of the Integrated Crop Management Conference*. 24.
https://lib.dr.iastate.edu/icm/2017/proceedings/24

View from the sky: Mapping corn nitrogen status at the watershed level

Chris Wilkins, database administrator/GIS specialist, Iowa Soybean Association; Suzanne Fey, data analyst, Iowa Soybean Association; Brad Wirt, GIS specialist/analysist, Iowa Soybean Association; Peter Kyveryga, Director of Analytics, Iowa Soybean Association

Introduction

To make informed decisions of how to better manage nitrogen (N) fertilizer, farmers and agronomists need the best and most reliable data about performance of fertilization systems. Regardless of the method used to determine N fertilizer requirements, users need to know whether past fertilization decisions were cost effective (too little or too much N) through feedback assessments.

Research about N management in corn has rapidly advanced during the last 10 years. Farmers and agronomists can use different recommendation systems such as the regional N recommendations that are based on yield response and profit optimization (Sawyer et al., 2006) or in-season N diagnostics tools such as chlorophyll meters or crop canopy sensors (Scharf and Lory, 2002; Holland and Sheperds, 2010). In addition, farmers can subscribe to many commercial N modeling tools that provide sidedress N rate prescriptions based on observed weather, potential corn yields and digital soil map information.

It is not easy to develop the best N recommendations in Iowa because farmers historically use practices with different timings, various application methods and N fertilizer sources or forms (Morris et al. 2017). That is why the renewed focus on 4R management– the right source, right rate, right timing and right placement– stresses the need to consider differences among these practices (IPNI, 2012).

One way to improve the feedback system is to collect, aggregate and analyze information from a large number of farmers' fields over time. These annual assessments can be used to quantify the effect of weather and field management on corn N status. Farmers participating in local groups or networks can collect information needed to quantify the risk of excessive or deficient N status. Ground truthing N responses will always be necessary.

Another way to further enhance the feedback system is through a view from the sky which provides a different perspective on the growing crop. There are several choices when considering digital imagery, including unmanned aerial systems, airplanes or satellites at different timing during the season. Regardless of the choice, to make accurate assessments of corn N status from the sky, the imagery needs to be supplemented by in-field observations.

The objective of this article is (1) to describe trends in farmers' N management practices from feedback evaluations during the last 10 years across Iowa and (2) illustrate the value of digital aerial imagery of the corn canopy to map N status within farmers' corn fields located in the Middle Cedar River Watershed of Eastern Iowa.

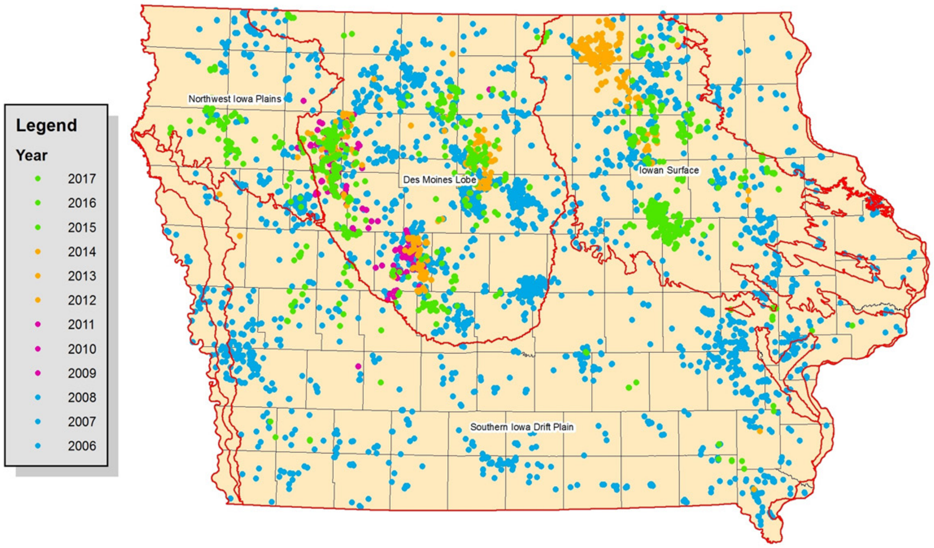


Figure 1. Location of 3,908 corn fields surveyed between 2006 and 2017 for late-season N status using aerial imagery of the corn canopy and corn stalk nitrate test.

Methods

Observations of late-season corn N status were collected from about 3908 corn fields using the end of season corn stalk nitrate test (CSNT) (Blackmer and Mallarino, 1996) and were guided by digital aerial imagery of the corn canopy (Figure 1).

The survey was designed to evaluate field-average N status and identify N stressed areas. To select sampling areas, color digital aerial imagery (red, green, and blue bands) was overlaid with a digital soil map to select four CSNT sampling locations within each field (Figure 2). Three corn stalk samples were collected within the three predominant soil types (based on their area within the fields) to characterize the field-average N status. The fourth sample was collected within an area that appeared to be the most N deficient, with lighter or less green or more yellow color of the corn canopy. This target deficient sample was collected to confirm that the more yellow color (less plant chlorophyll concentration) of corn canopy was associated with N deficiency but not with other plant stresses such as drought or excessive soil moisture, herbicide injury or early corn senescence.

Stalk samples were collected from two to five weeks after corn grain reached physiological maturity or black layer stage. Ten 8-inch stalk segments were cut 6-inches above the ground within each sampling area (Blackmer and Mallarino, 1996) that included two corn rows extending for about 30-40 ft. The collected samples were analyzed for stalk NO_3-N concentrations with a Lachat flow-injection analyzer (Lachat Instruments, Milwaukee, WI).

The late-season CSNT was developed to diagnose N sufficiency (i.e., N supply relative to N demand) or corn N status (Blackmer and Mallarino, 1996). The test results are reported as four NO_3-N sufficiency categories: deficient or low (<250 ppm), marginal (250-700 ppm), optimal (700-2000 ppm), and excessive (>2000 ppm).

- Deficient/Low; low N available (soil or fertilizer) results in likely economic yield loss.
- Marginal; economic yield responses from additional N applications would be equally likely.
- Optimal; N supply matches corn N demand so that and yield response to additional N is unlikely or equally likely.
- Excessive; N supply exceeded the plant demand and the yield response to additional N is unlikely.

CSNT data were aggregated as N sufficiency categories because nitrate concentrations are extremely skewed and because CSNT was developed to provide categorical expression of late-season corn N status.

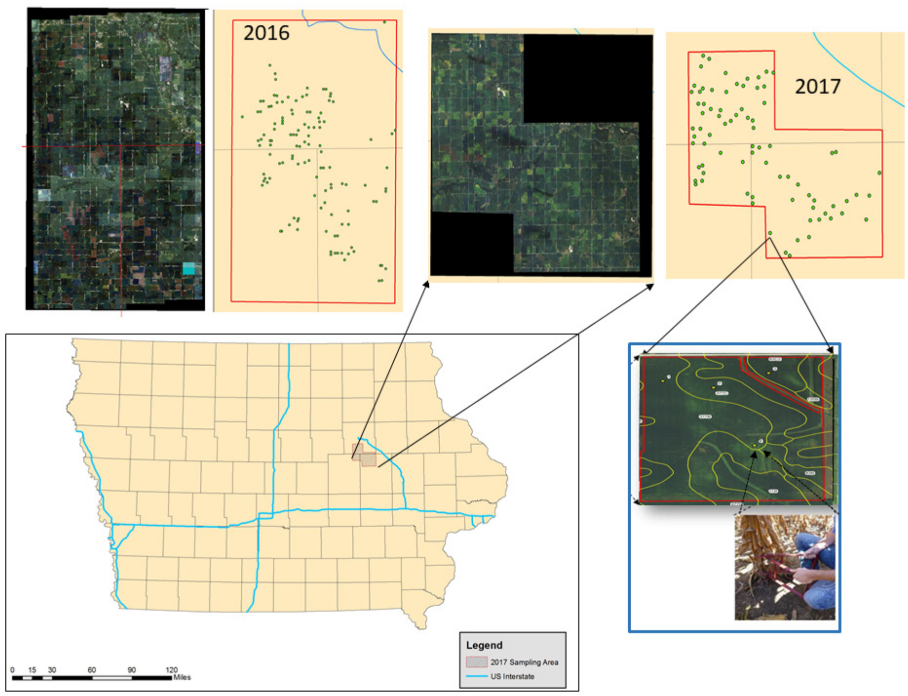


Figure 2. The area indicated is the Middle Cedar River Watershed which was imaged and surveyed for late-season corn N status in 2016 and 2017. The dots represent the corn fields evaluated.

Spatially interpolated monthly average rainfall data (4-km grids) were downloaded from the Iowa Environmental Mesonet, Agronomy Department, Iowa State University (http://mesonet.agron.iastate.edu/). Each field was assigned a rainfall value from a rainfall grid located nearest the field sampled.

A combination of N form and timing of application was classified as five predominant categories: Fall AA; fall-applied anhydrous ammonia; Fall SM, fall-injected liquid swine manure; SD UAN/AA, sidedress anhydrous ammonia or UAN; Spring AA, spring applied anhydrous ammonia; Spring UAN, spring-applied UAN. More information about the survey is describe elsewhere (Kyveryga et al., 2011, Kyveryga et al., 2012).

Imagery analysis - the Middle Cedar River Watershed

The aerial imagery was collected from an area of about 100,000 acres on August 23, 2016 and 134,185 acres Sept 2, 2017 using the "Leica ASD80 pushbroom sensor" in the Cedar River Watershed of Eastern Iowa (Figure 2). Four bands were collected: blue 428-498 nm, green 533-587 nm, red 608-662 and near infrared 833-887 nm. The images were 8 bit NRGB with and without the irradiance correction and two vegetative indexes, GNDVI and NDVI. The imagery spatial resolution was 1 meter.

The imagery reflectance values (green, red, GNDVI and NDVI) were first extracted for each of the four sampling areas (Figure 2). The relationship between reflectance values and the log of stalk nitrate values were established for each individual field using a linear mixed effects model with random slope and random intercept. In most of the fields, the green reflectance values were negatively correlated with the log of stalk nitrate values, suggesting that the lighter color on the imagery will likely correspond to the lower stalk nitrate values. Compared with NDVI and GNDVI, analyses that showed single green reflectance had the best predictability within and across all fields in both years. The imagery predictive ability was assessed by comparing the match between the observed vs predicted categories of corn N status. All statistical analyses were done using the Software (R Development Core Team, 2015).

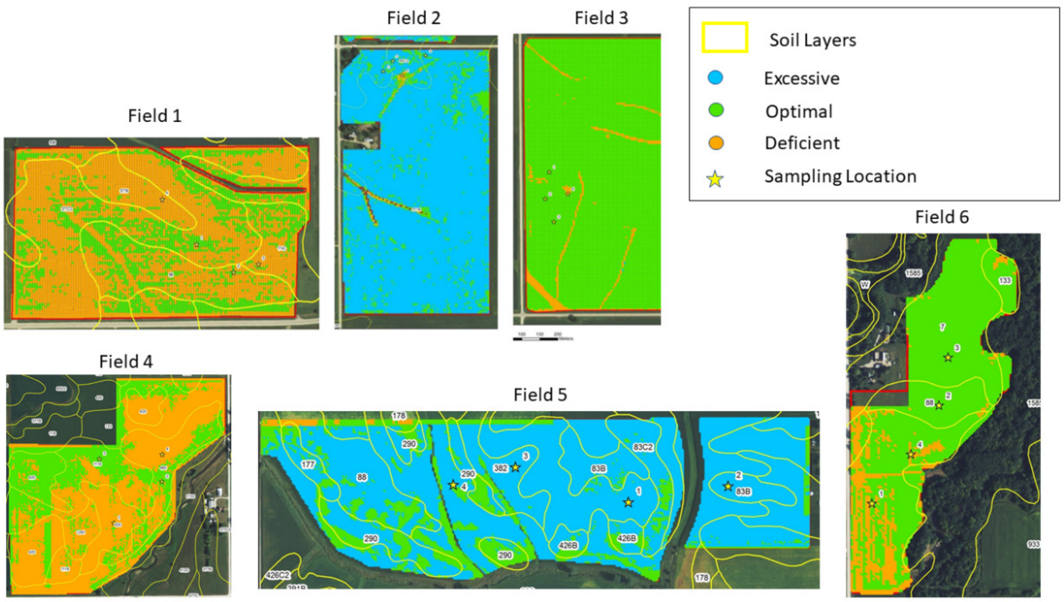


Figure 3. Examples of mapping within-field areas with predicted Deficient, Optimal or Excessive corn N status using analyses of green reflectance of the corn canopy and stalk nitrate test results from four sampling areas.

The observed equations for each field were used to identify cutpoint reflectance values that separated the Optimal from Excessive and Deficient N status. Then, the histogram of green reflectance values observed at 5 meters in each field were split into 3 categories to map likely Deficient, Optimal and Excessive areas (Figure 3).

Results and discussion

Historical trends in farmers' N management practices across Iowa

From the survey conducted across Iowa between 2006 and 2017, 20% to 30% of the fields were corn after corn (C-C). The remaining fields were corn after soybean (C-S). Fifty percent of all fields received AA, 27% UAN,15% swine manure and only4% of the fields received urea as the primary N form.

About 35 to 45% of the fields surveyed received Fall AA; 9 to 25%, Fall SM; 10 to 50%, Spring AA; 10 to 25%, Spring UAN; and from 10 to 25% of the fields received SD UAN or AA. In recent years, the observed trend is increased Spring AA and decreased Fall AA. The sidedress application as the primary practice is relatively small, although about 30% of fields had some sidedress applications.

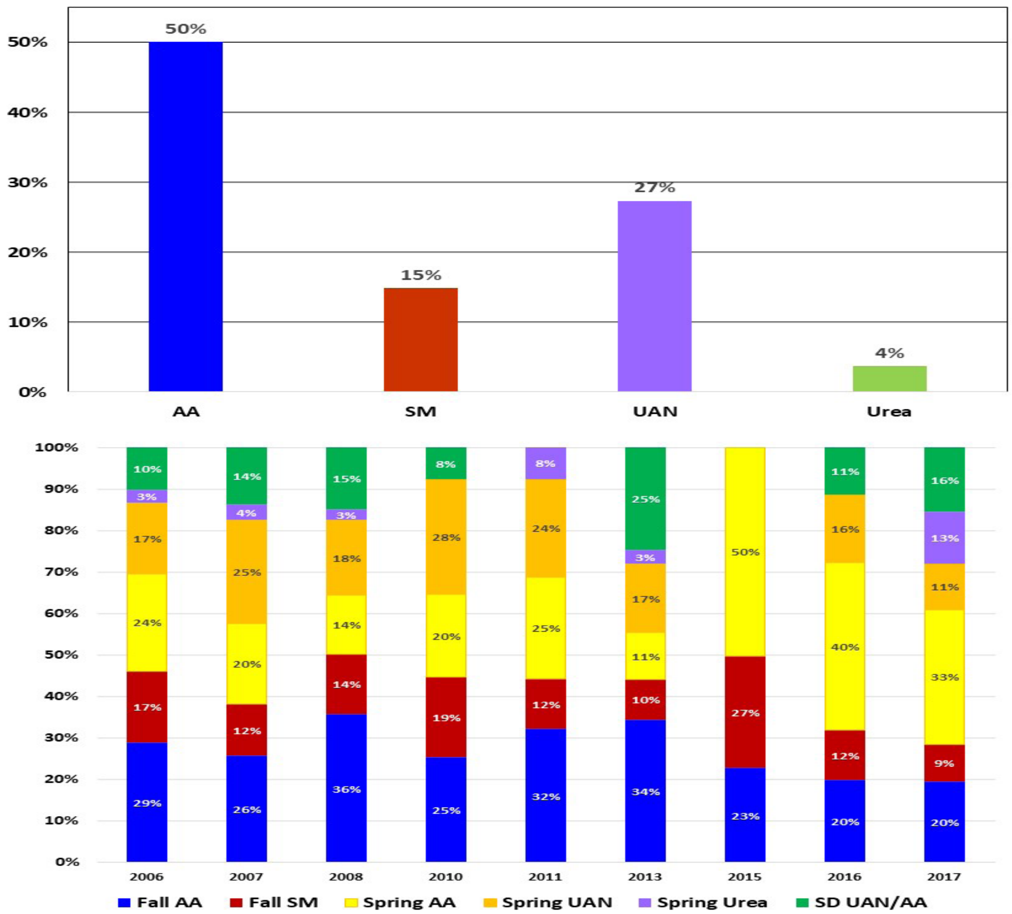


Figure 4. Percentage of corn fields by a predominant combination of timing application and N forms for 3908 fields surveyed between 2006 and 2017 across Iowa. The predominant practice is the largest percentage of the total N rate. The graphs include both corn after corn (C-C) and corn after soybean (C-S) fields. Fall AA=fall-applied anhydrous ammonia; Fall SM=fall-injected swine manure; SD UAN/UAN=sidedress urea ammonium nitrate solution or anhydrous ammonia; Spring AA=spring-applied anhydrous ammonia; Spring UAN=spring-applied UAN.

Risk of corn N deficiency for different landform areas

Based on the data collected (Figure 1), we developed an on-line N risk calculator http://iasoybeans.com:3838/NitrogenRiskCalculator/ (Anderson and Kyveryga, 2017). Users can locate their fields on the map, select the previous crop, specify N form and timing and enter the applied total N rate. The calculator uses site-specific daily rainfall during May through June to estimate the risk of N deficiency. The probabilities are classified into very low risk (<0.25), low risk (0.25-0.50), moderate risk (0.50-0.65), high risk (0.65-0.80), and very high risk (0.8-1.0)

Reference N rates for Northeast Iowa

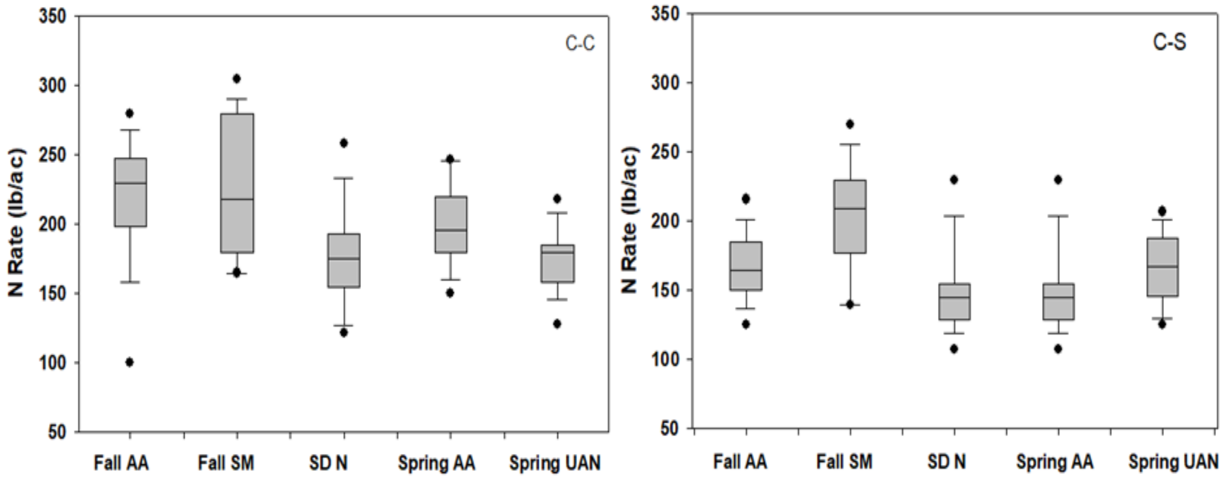
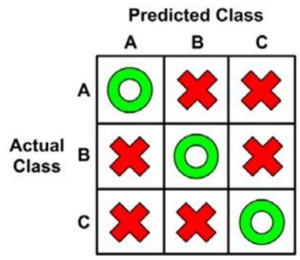


Figure 5. The distribution of N rates that farmers used for Optimal and Marginal corn N status for fields surveyed from 2006 to 2017 in Northeastern Iowa. The predominant practice is the largest percentage of the total N rate. The graphs include both corn after corn (C-C) and corn after soybean (C-S) fields. Fall AA=fall-applied anhydrous ammonia; Fall SM=fall-injected swine manure; SD UAN/UAN=sidedress urea ammonium nitrate solution or anhydrous ammonia; Spring AA=spring-applied anhydrous ammonia; Spring UAN=spring-applied UAN. Rates above those indicated by the gray boxes suggest that a field received too much N, or that the rate applied was higher than the optimal rates used by other farmers for the same geographic area.

Figure 5 shows ranges of N rates that farmers used to obtain Optimal and Marginal corn N status. These rates should be in a range of economical optimal rates. Fields with Fall AA and Fall SM received slightly higher rates to test Optimal than those for spring or sidedress. These rate ranges can be used as reference rates for specific geographic areas (Northeast Iowa) or different practices. The reference rates for C-C for commercial N ranged from 150 to 220 lb N/acre while the reference rates for Fall AA and Fall SM were by 30-40 lb N/acre higher, with much larger variability as well. The reference rates for C-S for commercial N ranged from 130 to 180 lb N/acre while the reference rates for Fall AA and Fall SM were by 20-30 lb N/acre higher. Higher reference rates for fall applications are due to potential higher N losses, and for swine manure could also be due to inaccurate estimations of rates applied and large variability in manure analyses.

Aerial imagery to map corn N status within fields



		Predicted			Correct Prediction (%)
		Deficient	Optimal	Excessive	
Observed 2016	Deficient	83	42		69
	Optimal	13	93	9	
	Excessive		44	71	
Observed 2017	Deficient	10	29	4	60
	Optimal	6	94	19	
	Excessive	3	44	53	

Figure 6. Accuracy of the green reflectance of the corn canopy to predict corn N status within 120 fields in 2016 and 83 fields in 2017 in the Middle Cedar River Watershed.

The green reflectance values were used to predict the observed corn N status. Each field had four sampling areas, one of them was a target deficient area with lighter or more corn canopy color than the rest of the field. (Figure 2). The prediction rate was about 70% in 2016 and 60% in 2017 (Figure 6) across all three N sufficiency categories. Although in general the imagery is not very sensitive to detect Excessive corn N status, none of the samples were misclassified as Deficient when they were Excessive and vice versa in 2016. There were four Deficient samples predicted as Excessive and three Excessive samples as Deficient in 2017.

The higher predictability in 2016 could be explained by larger areas with potential N deficiency (Figure 7). Higher deficiency was observed in 2016 due to above normal rainfall in June and July. Additionally, the rainfall observations indicated below normal levels in May, July and August in 2017.

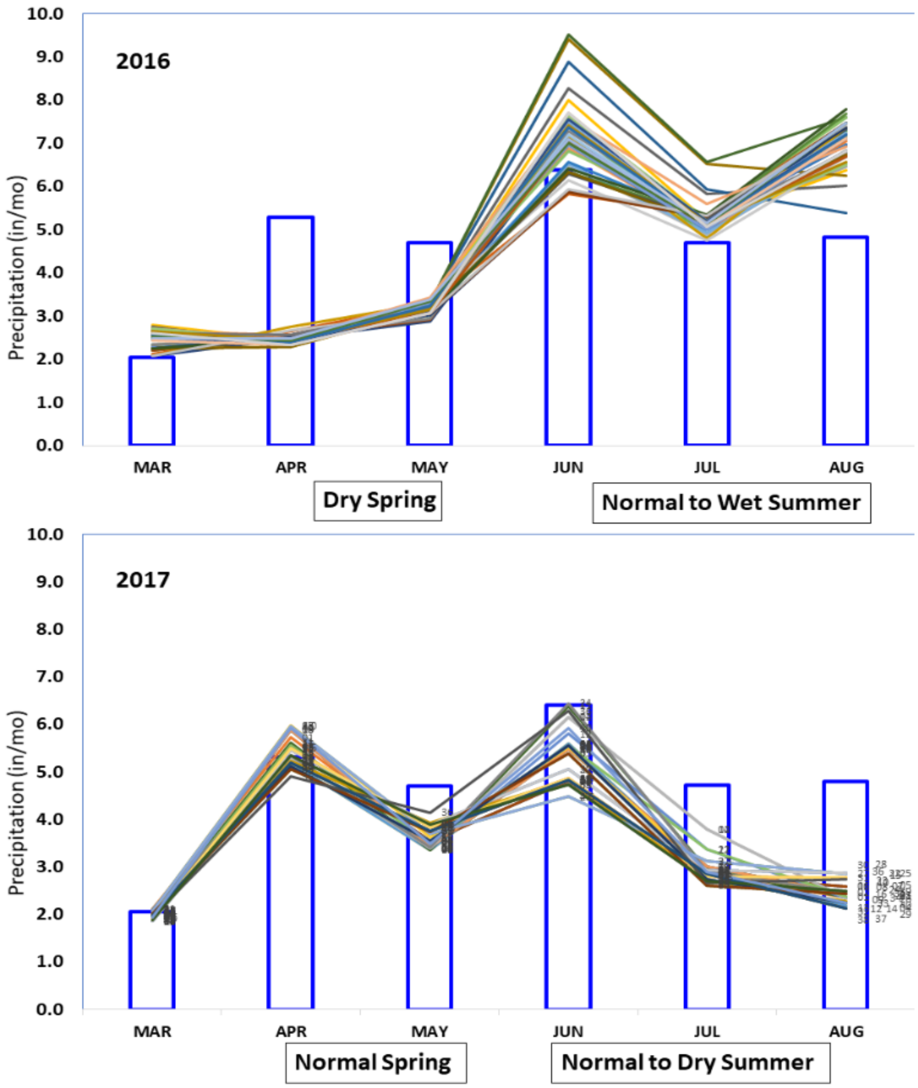


Figure 7. Site-specific monthly rainfall for the fields surveyed in the Middle Cedar River Watershed of in 2016 and 2017. Each line represents one field. Bars represent the 20 year average.

Figure 8 shows that the green reflectance of the late-season aerial imagery can help in predicting the final corn N status. As the corn canopy becomes less green (less chlorophyll concentration in the leaves) as reflectance values rise, the corn N status is more likely to be deficient or have lower stalk nitrate values. Contrary to the corn canopy color, higher total N rates (Figure 8 right) correspond to higher stalk nitrate test values.

The impact of total N rate on stalk nitrate values is smaller than the impact of the corn canopy reflectance. The absolute decrease in stalk nitrate values becomes larger with changes in green canopy reflectance than it does with changes in total N rates. These observations indicate that relying solely on total N rate in many agronomic and environmental assessments as the primary indicator of agronomic performance is not the best strategy. Since it is apparent that the degree of N loss, stress and variability in the canopy is affected by more than one environmental factor or field management.

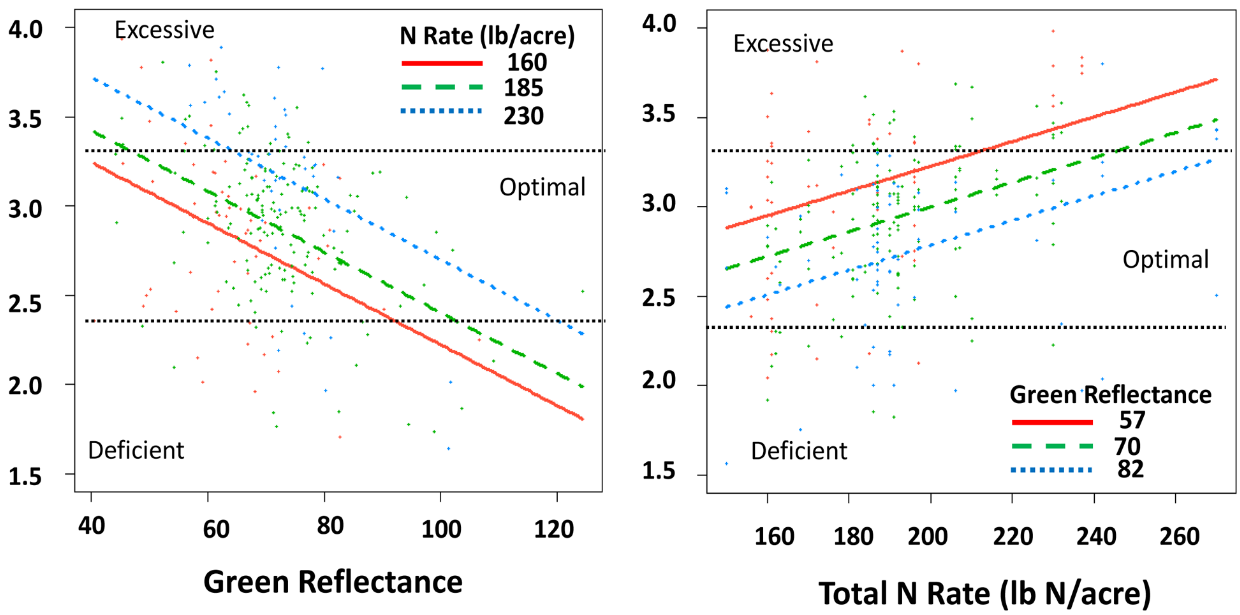


Figure 8. Relationship between green reflectance of the corn canopy and total N rate with log stalk nitrate concentrations for corn fields surveyed in the Middle Cedar River Watershed in 2017. Corn stalk nitrate values are usually extremely skewed so they need a log transformation. All fields were used in analyses.

Summary

Recently, farmers have started using different sources of digital aerial imagery, mostly for visual assessments and to help in field scouting. Here we showed how the late season aerial imagery within in-field observations can be used to determine whether past fertilizer decisions were effective. The green reflectance of the corn canopy correctly predicted the corn N status from 60 to 70% of the time.

This approach can be used in both agronomic and environmental assessments. Using aerial imagery with in-field observations, corn N status can be mapped within fields and this approach can be extended to whole watersheds or even a regional level. It's possible to expand this approach to be utilized by 4R management and identify the effects of cover crops and other conservation practices and weather.

The imagery analysis shown here can complement nutrient or manure management planning which is primarily focused on N rates used by farmers with additional field information.

Acknowledgment

Studies described here were partially funded by the United State Department of Agriculture Natural Resource Conservation Services (NRCS) Grants, NRCS Nutrient Adaptive Management Project, Integrated Farm Livestock Management Project from the Soil Conservation Division of the Iowa Department of Agriculture and Land Stewardship, Iowa Soybean Association Checkoff dollars. We are very thankful to all farmers, agronomists, technical providers, industry professionals, and partner university scientists who participated and contributed to the on-farm studies described in this publication.

References

Anderson, C.J. and P.M. Kyveryga. 2016. Combining on-farm and climate data for risk management of nitrogen decisions. Climate Risk Management. 13:10-18.

Blackmer, A.M., and A.P. Mallarino. 1996. Cornstalk testing to evaluate nitrogen management. Iowa State Univ. Ext. Bull. Pm-1584., Ames, IA.

Holland, K.H, and J.S. Schepers. 2010. Application model for in-season fertilization of corn. Agronomy J. 102:1415-1424.

Kyveryga, P.M., T.M. Blackmer, and R. Pearson. 2012. Normalization of uncalibrated late-season digital aerial imagery for evaluating corn nitrogen status. Preci. Agric. 13:2-16. DOI 10.1007/s11119-011-9231-8.

Kyveryga, P.M., T.M. Blackmer, R. Pearson, and T.F. Morris. 2011. Late-season digital aerial imagery and stalk nitrate testing to estimate the percentage of areas with different N status within fields. J. Soil Water Cons. 66:373-385.

R Development Core Team. 2015. R: A language and environment for statistical computing.

Morris, T.M., S.T. Murrell, D. B. Beegle, J.J. Camberato, R.B. Ferguson, J. Grove, Q. Ketterings, P.M. Kyveryga, C. A.M. Laboski, J. M. McGrath, J. J. Meisinger, J. Melkonian, B. N. Moebius-Clune, E. D. Nafziger, D. Osmond, J. E. Sawyer, P. C. Scharf, W. Smith, J. T.

Spargo, H. M. van Es, H Yang. 2017. Strengths and Limitations of Nitrogen Rate Recommendations for Corn and Opportunities for Improvement. Agronomy J. (first look online).

Sawyer, J., E. Nafziger, G. Randall, L. Bundy, G. Rehm, and B. Joern. 2006. Concept and rationale for regional nitrogen rate guidelines for corn. Iowa State Univ. Ext. Ames. IA https://store.extension.iastate.edu/product/12240

Scharf, P.C., and J.A. Lory. 2002. Calibrating corn color from aerial photographs to predict sidedress nitrogen need. Agron. J. 94:397-404.